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Troubles with Cognitive Neuroscience

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Résumé : En quelques mots, nous présentons les principaux problèmes des neurosciences cognitives : le problème de la liaison, la localisation, la différenciation–intégration dans le cerveau, les difficultés créées par l'imagerie cérébrale, et l'optimisme *versus* scepticisme dans les neurosciences cognitives. Étonnamment, même s'il y a de plus en plus de résultats expérimentaux ces dernières années, nous ne remarquons pas de réel espoir de résoudre ces difficultés dans le futur. Les neurosciences cognitives sont basées sur des « corrélations » entre états mentaux et neuronaux, principalement issues de l'imagerie cérébrale — fMRI de ces deux dernières décennies. Nous voulons suggérer que ces « corrélations » sont dépourvues d'un quelconque arrière-plan ontologique. Dans ce contexte, nous devons répondre à la question suivante : les neurosciences cognitives sont-elles une vraie science ou une sorte de « nouvelle ingéniérie » ?

Abstract: In few words, we present the main actual problems of cognitive neuroscience: the binding problem, localization, differentiation–integration in the brain, the troubles created by the brain imaging, and optimism vs. skepticism in cognitive neuroscience. Surprisingly, even if there are more and more experimental results in recent years, we notice no real hope for solving these troubles in the future. Cognitive neuroscience is a science constructed on "correlations" between mental and neuronal states, mainly furnished by the brain imaging—fMRI of the last two decades. We want to suggest that "correlation" lacks any ontological background. In this context, we have to answer the following question: Is cognitive neuroscience a real science or a kind of "new engineering"?

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1 Cognitive neuroscience today

In this paper, we intend to present a general image of cognitive neuroscience by means of a brief presentation on the main topics: the binding problem, localization, differentiation–integration in the brain, the problems of the brain imaging, and finally the debate "optimism vs. skepticism" in cognitive neuroscience as "science". The state of affair is somehow paradoxical: there have been incredibly many people working in laboratories of cognitive neuroscience in the last 20 years, and an avalanche of data has become available based on a variety of research techniques, such as fMRI, EEG, MEG, and TMG. In addition, information is widely shared online, many workshops and conferences take place in the world, but paradoxically, the mind–brain problem[1] and other related problems are still unsolved. Therefore, this question arises: "Can we solve these problems in the future?" This question is strongly related to another one: "What kind of science is cognitive neuroscience?"

Cognitive neuroscience is a sub-domain of cognitive science. One of the main problems in cognitive science was the problem of representation[2] (and consciousness)[3] during the 1990s and at the beginning of the 21st century. We recall the main approaches for representation: computationalism, connectionism and the dynamical system. More recently, we have seen the emergence of approaches like embodied and situated cognition. All these approaches were designed to provide answers to the main questions regarding the existence of mental representations, their content and format. Paradoxically, even though the majority of researchers accept some form of reductionism, questions about the status of the mental have remained, in cognitive science, the main framework being the correlations of mental states with neuronal patterns of activation. Nevertheless, these relationships ("correlations") create serious problems in cognitive neuroscience. There are important people in cognitive neuroscience (and quite a lot in philosophy) who reject the identity theory.

In philosophy of cognitive (neuro)science there have been many debates regarding the relationship (difference) between mental and neuronal states. Is this difference ontological, epistemological, linguistic or are these states attributes of an unknown substance (Spinoza, and some people in philosophy of mind today)? The identity theory, the brain producing the mind[4] and different kinds of "emergence" (see [Vacariu 2008]) are the main paradigms

1. In this article, we do not propose a new alternative to the mind–brain problem. For an alternative to this problem, see [Vacariu 2005, 2008, 2011, 2012] and [Vacariu & Vacariu 2010].

2. For a summary of this problem, see [Vacariu, Terhesiu & Vacariu 2001].

3. In order to preserve a rigorous framework of this paper, consciousness and the self will not be discussed in this paper.

4. The philosopher Searle elaborated this approach in 1992 [Searle 1992]. Offering a lot of arguments from cognitive neuroscience, Frith also believes that the brain "produces" the mind [Frith 2007].

that dominate cognitive neuroscience today.[5] Throughout the last 15 years, there has been a significant progress in cognitive neuroscience. Particularly, the advances in functional neuroimaging technology have offered real hope in understanding the relationship between mental states and the activity of neuronal patterns. Nevertheless, even if such investigation tools are very helpful, it seems unlikely that in the near future, researchers will finally find the real solutions to the main problems of cognitive neuroscience. On the contrary, the new investigation tools generate more and more controversial answers to the main problems of cognitive neuroscience. Will these empirical results lead to the right conclusion about the main problems of cognitive neuroscience? In the following sections, we will shortly present the main problems of cognitive neuroscience mentioned above, in the end inquiring about the general framework in which the majority of people work in cognitive neuroscience.

2 The binding problem

One problem in cognitive science is the binding problem. Various researchers bring up different forms of binding: spatial (location) or temporal, conscious or unconscious, visual (linking together color, form, motion, size, and location of a perceptual object or binding various perceptual objects), auditory, cognitive (explains how a concept is connected to a percept), binding in language understanding, in reasoning, cross-modal binding, sensory-motor binding, memory binding and the causes of a unified conscious experience (for instance, [Velik 2010], [Plate 2007], etc.). Velik writes that the binding mechanism is "almost everywhere in the brain and in all processing levels", [Velik 2010].[6] Let us analyze the visual binding: any object, for instance, has certain visual features (color, orientation, motion, texture, and stereoscopic depth) that are linked to particular neuronal areas. In the past, perception of color was correlated with V4, motion with MT/V5, and so on. Due to recent discoveries, such correlations are much more problematic. Since we perceive only a singular entity (the object) with various features, then a mechanism that binds these features together in a single entity becomes necessary. There are many questions regarding the binding problem. For instance, what mental processes (conscious or unconscious) create the binding among various features? If there are still quite strong debates regarding the correlations between a particular mental feature (for instance, color) and some neuronal areas, it is much more difficult

5. The label "cognitive neuroscience" "was coined in the late 1970s in the backseat of a New York taxi when Mike Gazzaniga was riding with the eminent cognitive psychologist George Miller to a meeting to gather scientists to join forces to study how the brain enables the mind", [D'Esposito 2010, 204].

6. Noticing that the binding problem is "almost everywhere in the brain", maybe something is wrong with the framework of thinking that dominates cognitive neuroscience. We have to point out that some people consider that the binding problem is a pseudo-problem (see [Vacariu & Vacariu 2011]).

to answer the question "What neuronal mechanism has to be correlated with the unity of a perceived object?"

Let us introduce in a few words the two approaches regarding this problem. The first alternative is the quite old Treisman's feature-integration theory (FIT), the second is the synchronization or temporal coding theory (or temporal binding) that is still controversial. In Treisman's FIT, attention plays an essential role in the binding process, but attention is a very unclear notion in cognitive neuroscience today. Anyway, Treisman herself modified ("improved") her approach during years (maybe such modifications could be viewed as more and more complicated Ptolemaic epicycles). Among many critics against FIT, Velik recalls that, in some situations, the object recognition does not depend on top-down processes [Velik 2010]. According to Gray, there have "to exist mechanisms that act prior to attention and also serve to attract it" Gray (1999) in [Velik 2010, 998]. There are some experiments arguing that attention has no role in binding processes. The features remain bound in short-term memory without the need of attention [Delvenne, Cleeremans & Laloyaux 2010, 108]. Making some experiments on the delay recall task, [Gajewski & Brockmole 2006] try to clarify the relationship between attention and visual working memory. Treisman believes that attention is indeed necessary for the binding object features and has a role for the information that is accounted within visual working memory. Also without attention, there are illusory conjunctions. Nevertheless, without attention, we do not remember features independently but "integrated objects are stored in visual working memory without need for continued attention" [Gajewski & Brockmole 2006, 581]. Some people believe that, in visual working memory, the memory processes retain the object as a whole or it is deleted from memory [Gajewski & Brockmole 2006, 586]. Others consider that the binding process does not need a special mechanism of selective attention [Vul & Rich 2010, 1173]. Treisman's FIT is still very controversial in our days.

Quite many scientists (von der Malsburg, Engel, Singer, Fries, etc.) consider that synchronization of the neuronal processes is the real solution for the binding problem. The perceptual features of an object are bound through the synchronized oscillations. It seems that the oscillation theory is the most accepted alternative one today, even if there are quite many critics against it. From our viewpoint, we consider that maybe we can link synchronization with the processes of consciousness, but it does not solve the binding problem. The research in recent years produced more confusion and unclear results regarding the role of oscillations in cognitive/consciousness processes. Tallon-Baudry mentions that, in the first period of research, each frequency band was associated with a cognitive function or state: delta waves were associated with sleep, theta band with memory, alpha wave with vigilance fluctuations (or with mental imagery and other mental processes, as suggested by [Baars & Gage 2010, 270]), beta and gamma ranges with active awake stages and later with feature binding, attention, and memory [Tallon-Baudry 2010, 239], [Tallon-Baudry 2009]. The associations between mental functions/states and oscillations have recently changed quite dramatically. We can quote Tallon-Baudry and assume that "the functional role of oscillatory synchrony in distinct frequency bands may simply depend on the functional specialization of the area that generates these oscillations (Tallon *et al.* 2005), much as the functional significance of ERPs depends on the areas that generate them" [Tallon-Baudry 2010, 240].[7] Tallon-Baudry considers that, in our days, there is *no strict correspondence between a frequency band and a cognitive process* [Tallon-Baudry 2010, 239, 325], [Tallon-Baudry 2009]. The conclusion is that, in cognitive neuroscience, there is no alternative to the binding problem accepted by the majority of researchers.

3 Localization

The avalanche of empirical results furnished by fMRI created a tremendous impulse in cognitive neuroscience in the last two decades. Between two extreme theories (the grand cell theory vs. the holistic theory), based on recent research, the majority of people consider that each mental state (a feature of a perceived object, for instance color) has to be correlated with some distributed neuronal areas. From hundreds of articles published each year on fMRI, we will briefly analyze an experiment with surprising empirical results in mirroring the actual state of affairs regarding the famous notion of localization. In a perceptual scene, the human observer can detect various objects in a specific area (segmentation, the notion used by Bartels). The properties of each perceptual object are, for instance, its boundaries, color, motion, direction and distance to the observer. The researchers need to solve the following problem: what neural mechanisms create the links among segmentation, feature binding and attentional selection [Bartels 2009, 300]? Based on recent empirical evidence, Bartels claims that even at the early visual cortex (V1 and V2) such connectivity takes place! Subsets of neurons from V1 and V2 are responsible for the border-ownership of edges and the same subsets are directly modulated by top-down attention [Bartels 2009, 300]. However, neurons from V2 are also responsible for color and motion.[8] Bartels indicates that the properties of a given object far exceed the small field of view of V2 neurons through feedback mediated by myelinated (fast conducting fibers of neurons with much larger receptive fields, similar with the neurons from V4). Interestingly, this feedback

7. For very recent critics of the synchronized oscillations see, for instance, [Dong, Mihalas, Qiu *et al.* 2008]. O'Herron and von der Heydt acknowledge that the neuronal processes responsible for the continuity of human perceptual representations are unknown [O'Herron & von der Heydt 2011]! In fact, we have here not only the binding problem but also the 'endurance' problem of mental representations. Both problems are still unsolved in our days. More details about the temporal coding theory, see [Vacariu & Vacariu 2011].

8. Haynes mentions that "even if V1 does not encode colour sensations, it could still encode other, simple features of conscious experience, such as brightness or contrast sensations" [Haynes 2009, 198].

mediated not only the spatial binding in V2, but also color and motion ("features that are processed within V2's anatomically segregated thin and thick stripes, respectively") [Bartels 2009]. Against the synchronization alternative, other experiments suggest that the same neurons (mainly V2) mediate the border ownership and the basic visual features. Moreover,

> No evidence has been found that synchronous firing "tags" same-border neurons, as classic theories on the binding problem have proposed [...]; instead, this seems to be mediated by a plain enhancement of the neural firing rate [...]. Nevertheless, those select neurons that are capable of coding for border-ownership have the distinct hallmark of increased synchronous firing that does not indicate same/different border coding, but that indicates that they are part of a network with far-reaching connectivity. [Bartels 2009, 301]

Bartels concludes that these experiments show that the early visual cortex mediates border-ownership, feature binding and object-based attentional selection. In this context, let us introduce the very interesting experiment realized by Seymour *et al.* ([Seymour, Clifford, Logothetis *et al.* 2009], Bartels signed this article, too) regarding localization of color, motion and the *conjunction* between color and motion. They argue that both features are processed by distinct neuronal areas: the color is processed by the blobs V1, thin strips of V2 and V4, while the motion is processed by the layer 4B of V1, thick stripes of V2 and V5/MT. Thus, motion and color seem to be segregated at the cellular level, lesions studies (lesions to V4 impair color perception but spare motion perception, lesions to the V5/MT impair motion perception but spare color perception) confirming this segregation [Seymour, Clifford, Logothetis *et al.* 2009, 177]. The question is if we accept such a functional segregation, then how and where does the binding of these features occur?[9] Seymour *et al.* conducted an essential visual experiment. The human subjects perceive two transparent motion stimuli, each stimulus has the same two circle-colors and two motions, the difference being the direction of movement of circle-color (clockwise and counterclockwise). They indicate that "the double-conjunction stimuli would be indistinguishable without conjunction-specific responses, as all four feature specific units are active in both conditions" [Seymour, Clifford, Logothetis *et al.* 2009, 178]. Based on the results of fMRI, the main conclusion of this experiment is that the primary visual cortex includes information not only about motion direction and color hue but also about *conjunction* of these two features:

> Whereas some areas showed better performance as well as biases for decoding one feature over the other (e.g., V5/MT+ for motion;

9. It "remains a matter of debate whether visual-feature binding is mediated by a temporal code [...], by communication between visual areas [...], by feedback connections to early visual areas [...], or by representations at higher, cognitive stages [...]" [Seymour, Clifford, Logothetis *et al.* 2009, 177].

> V4 for color), information about both features and their conjunction was present in nearly every visual cortical region. [Seymour, Clifford, Logothetis *et al.* 2009, 178]

However, the authors of this work emphasize the limits of fMRI through spatial-temporal resolution. Whitney emphasizes some problems with Seymour *et al.*'s "clever technique": beside lesions, we have to take into account the psychological and physiological models of binding based on higher-level mechanisms; furthermore, the feedbacks from fronto-parietal attentional region may create the conjunctions; under the illusions framework, it is possible for the mechanism of feature binding not to be recruited for unambiguous visual stimuli [Whitney 2009, R252–R253]. Seymour and his colleagues are aware of the overall limitations of neuroimaging technologies, such as fMRI and PET, as these machines might show us only a part of what actually happens in the brain.

There are also other elements that could further complicate the whole image of localization and even of the binding problem, such as the role of neurotransmitters, the feedback from different parts of the brain, the synchronized oscillations, famous Edelman's "re-entrant processes", Raichle's "default network" [Raichle 2006], [Raichle & Mintun 2006], [Raichle & Snyder 2009] and Libet's "cerebral mental field" [Libet 2006]. We have to be aware of the particular conditions of observing some processes/entities, either mental or neural, when we analyze the results of the neuroimaging technology. The conjecture regarding the conjunction between color and motion based solely on the firing neurons might be hazardous, as neurons are probably doing "more than fire spikes", as Baars and Gage observe [Baars & Gage 2010, 96].[10] Like the binding problem, localization is constructed on the same problematic notion of "correlations". Therefore, localization is itself a problematic notion[11] and hence we have to answer the following question: can a real science be constructed on "localizations"?

4 Optimism in cognitive neuroscience

One of the most important philosophers in cognitive (neuro)science, Bechtel is an optimist, even if a couple of years ago, he admitted that the process of perceiving a simple object had to be correlated with more than 30 neuronal areas [Bechtel 2008]. Bechtel was convinced that localization (and "decomposition")

10. Derrfuss and Mar draw the attention upon the fact that we are already "lost in localization" [Derrfuss & Mar 2009]; Globus and O'Caroll propose "holonomy" instead of localization [Globus & O'Carroll 2010].

11. "What is the point of having all of these retinotopic maps? (And there are known to be many more than these three!) Does each area—V1, V2, and V3—serve a different function? Do they represent different properties of the visual world?" [Banich & Compton 2011, 161].

of mental states in the brain would be successful in the future, pleading for the *heuristic theory of identity* [Bechtel 2008]. Later, Bechtel considered that the notions of "localization" and "brain areas" needed to be re-conceptualized [Bechtel 2013]. His new alternative is a combination of mechanisms with the dynamical system approach, i.e., the dynamical mechanisms, and the explanation of "endogenous activity of the brain" [Bechtel 2013]. He believes that in order to explain cognition through the neuronal processes, we need to clarify this intrinsic activity of the brain (related to Raichle's default network). Bechtel already tried to combine reductionism with emergence [Bechtel 2008] or integration with differentiation of operations [Bechtel 2009]. In order to support these ideas, Bechtel mentions Sporns and Zwi's (2004) "*dual role of cortical connectivity*": the *functional specificity* of certain cortical areas that manipulate specific information and the *integration* of this kind of information [Bechtel 2013]. Bechtel insists in combining integration with parallel localization of certain various functions. From our viewpoint, we notice that the functional specificity and the integration are quite similar notions to notions as the binding problem and localization.

Continuing the optimism paradigm, we analyze the latest work of people from Gallant's laboratory [Nishimoto, Vu, Naselaris *et al.* 2011].[12] In 2011, Nishimoto *et al.* (Gallant's laboratory) published an article about a new method for "mind reading" (this work being considered among the best achievements in the last 15 years in cognitive neuroscience) [Nishimoto, Vu, Naselaris *et al.* 2011].[13] With a computer program and based on the fMRI results, the researchers constructed a quantitative model of brain activity. Using the brain activity measurements, Nishimoto *et al.* reconstruct natural movies seen by three human subjects. It is the first study of reconstructing dynamic stimuli (natural movies) through the brain activity using fMRI. In the past, only static pictures were reconstructed, the main problem being that the blood oxygen level-dependent (BOLD) signals measured by fMRI are much slower than the neuronal activity in relationship with dynamic stimuli. This new "motion-energy encoding" model furnishes a mapping between stimuli and evoked fMRI signals. It has to match two components, visual motion information and slow hemodynamic mechanisms, in order to "recover fine temporal information" from slow BOLD signals [Nishimoto, Vu, Naselaris *et al.* 2011, 1641]. The researchers of Gallantlab focus on signals received by the early visual neural areas V1 (the functionality of this neural area being quite well studied), V2 and V3 (all areas being in occipitotemporal cortex lobes). The measured training data of brain activity (BOLD signals evoked by 7,200 color natural movies, each movie presented once) used to match an encoding model for each voxel from posterior and ventral occipitotemporal visual cortex. Then

12. About the previous work of the same laboratory, see their work and Uttal's investigation [Uttal 2011].

13. On the Gallantlab's webpage (gallantlab.org), "Research section", we can see one of the latest news: "Our work on reconstructing visual experiences evoked by natural movies was selected as one of Time Magazine's 50 Best Inventions of 2011."

they use a Bayesian decoder to reconstruct movies from the evoked BOLD signals, i.e., combining the "estimated encoding models with a sampled natural movie prior, in order to produce reconstructions of natural movies from BOLD signals" [Nishimoto, Vu, Naselaris *et al.* 2011, 1642]. Comparing the fMRI data and the details of each movie, the computer program constructs "dictionaries" for shape, edge and motion. Each voxel has such a dictionary. The subject watches a second set of movies and new fMRI data are collected. Using the computational models constructed on the first set of movies, the second set of movies is reconstructed only from the second fMRI data [Nishimoto, Vu, Naselaris *et al.* 2011]. Using " 'pick a card, any card' magic trick", people working in Gallantlab do not even try to offer an alternative to the binding problem.[14] Even if Uttal admires Gallantlab's work, he concludes that mostly they were able to show distinctive fMRI responses from a number of visual cortical areas (V1, V2, V3, V3A, V3B, V4, as well as the lateral and anterior occipital cortex) that could be used to identify images from the training set. What they did not do was to take fMRI images and directly plot from them pictures of the original stimuli; once again, they selected pictures from their library based on the pattern of activations. This is not reconstruction *per se*, but a selection from a predetermined "deck of cards" [Uttal 2011, 114]. On the same line of research, using "diffusion-weighted imaging (DWI), an MRI technique that measures the propensity of water to travel along myelinated axons", Saygin *et al.* show that only the activation of the individual's pattern of structural connectivity (fusiform face area, FFA) predicts the function of face selectivity [Saygin, Osher, Koldewyn *et al.* 2012].[15] In other words, brain structure (extrinsic connectivity) determines function. Therefore, there is a strong relationship between structural connectivity and function. This relationship has the same difficulties as the binding problem and localization.

14. In their previous works, they write that this problem "is analogous to the classic 'pick a card, any card' magic trick" [Uttal 2011, 113].

15. In a very recent article, using diffusion spectrum MRI (DSI), Van Wedeen *et al.* offer a completely new image regarding the anatomical structure of the brain that is wired in a rectangular 3D grid structure [Wedeen, Rosene, Wang *et al.* 2012]! DSI acquires a detailed image of the three dimensional pattern of water diffusion by measuring diffusion in dozens to hundreds of directions. "Far from being just a tangle of wires, the brain's white-matter connections turn out to be more like ribbon cables—folding 2D sheets of parallel neuronal fibers that cross paths at right angles, like the warp and weft of a fabric." Essentially, this grid structure "is continuous and consistent at all scales and across humans and other primate species" [Wedeen, Rosene, Wang *et al.* 2012]. So, the brain is not a mechanism as complex as we have thought! On the contrary, as a result of evolution, the brain is quite a simple machinery. Paradoxically, even within this new view, the mind–body problem has no chance to be solved in cognitive neuroscience or philosophy of mind in our days.

5 Skepticism in cognitive neuroscience

Emblematic for the contemporary skepticism regarding the localization of certain mental functions through the imagistic procedures is Uttal (who is not a philosopher, but a researcher in cognitive neuroscience). His main book against localization was published in 2001, but Uttal pushed further these ideas in a book published in 2011. Even if he accepts the identity theory, Uttal illustrates many arguments against localization. In an ontological postulate, Uttal considers that the mental processes are the results of interactions from the micro-level of the brain. Since fMRI and PET "localize" the mental functions at the "macro-level" (the large neural patterns), the results are completely wrong [Uttal 2011, 11]. Through a corollary of this postulate, Uttal believes that "the neural network approach is computationally intractable" and thus the mind–body problem cannot be solved [Uttal 2011, 26]. Moreover, he undertakes a general view in cognitive neuroscience that the "brain activity associated with mental activity is broadly distributed on and in the brain" [Uttal 2011, 45].[16] We can see an epistemological-ontological framework that shows us that the neural networks are indeed "computationally intractable". We can find no mental computations within the brain.

Uttal believes that localization through fMRI and PET is the wrong method of identifying mental states. Uttal claims in his first epistemological postulate for neuroscience that the "brain activity associated with mental activity is broadly distributed on and in the brain. The idea of phrenological localization must be rejected and replaced with a theory of broadly distributed neural systems accounting for our mental activity" [Uttal 2011, 45].[17] For Uttal, the main reason of this point is that the actual tools operate at the wrong "level of analysis" and the mind would be better grasped not at

16. Important is that the "a priori no brain imaging or electrical recording activity, no matter how direct they may seem to be in recording the activity of the brain, can in principle provide solutions to the mind–brain problem" [Uttal 2011, 26]. Moreover, "many different cognitive processes can activate the same area or system of areas of the brain" [Uttal 2011, 55] and "many different regions of the brain have been activated during any kind of cognitive task" [Uttal 2011, 45].

17. "All brain regions are involved in learning, memory, and plasticity, which can be considered as different methods for evoking long-lasting adaptive changes in the brain" [Baars & Gage 2010, 541]. Lost in localization! Anyway, we have to link this widely distributed neuronal network correlated with any mental state with Baars' "global workspace" [Baars & Gage 2010] supported by Dehaene's global neuronal workspace and by Raichle's default mode network: "But, just as we will not understand evoked activity without first understanding intrinsic activity, so we will not understand consciousness without first understanding non-conscious activity, for in both instances the latter dominates the former" [Raichle 2011, 155]. Haynes also believes that Baars' global workspace theory seems to be the best alternative since many experiments have showed that the distributed areas are involved for each mental task [Haynes 2009]. Following the same route of holism, Bressler and Menon strongly argue that cognition is much better explained at "large-scale networks" [Bressler & Menon 2010].

macroscopic but microscopic level. Against localization, he is convinced that almost certainly, any mental task/function/state (sensation, perception, simple thought) involves the entire brain. The parts of the brain are all somehow interconnected; it is not possible to isolate the neural patterns that correspond to any cognitive process; consciousness and all its relatives (thinking, reasoning, decision-making, problem solving, and intelligence) are the most problematic notions in cognitive neuroscience, etc. There are no clear definitions of some mental states like emotion, attention or consciousness[18] and probably such states are general functions and not modules of cognition. In conclusion, we can suggest that Uttal's perspective is the strongest skepticism in cognitive neuroscience.

Hardcastle criticizes the modularity of mind hypotheses [Hardcastle 2007], [Hardcastle & Stewart 2002]. The main attack is not only against the fact that there are no empirical data for this strategy but also against the theoretical framework. These authors believe that none of those three methods (localization and single cell recordings, lesion studies and the assumption of brain constancy, functional imaging), in which the neuroscientists believe in finding the modularity of the brain, offers viable results.[19] Hardcastle raises many essential questions on perception, memory, attention, combination of information from various sensory modalities, localization/reduction, methodologies in cognitive neuroscience, etc. It is not surprising that researchers become more and more interested in developmental neurobiology (an area that becomes more and more molecular) or in the interactions between genes and environment to explain the mysteries of cognition. The main question remains "how the brain coordinates itself across neurons to produce global effects" [Hardcastle 2007, 298]. If a specialist in philosophy of cognitive neuroscience asks such questions after so many years of working in this field, we have to inquire about the paradigm of thinking in which the majority of people work in cognitive neuroscience.

In the past, it was believed that local filed potential (LFPs) and spiking were correlated with bold-oxygen-level-dependent (BOLD) response. The work of Logothetis and collaborators showed, among the first, that in some cases, there are clear and strong LFPs signals but the spikes are absent (Logothetis *et al.* (2001); Goense and Logothetis (2008) in [Logothetis 2008]). Moreover, Logothetis claims that even if the brain's architecture is modular, we would never be able to map mind modules onto brain structures, because a unified mind has no components to speak of" [Logothetis 2008, 869]. Obviously, the traditional "input-elaboration-output" scheme (corresponding to the "perception-cognition-action model") is "probably a misleading oversimplification" [Logothetis 2008, 872]. Moreover, in 2008, Logothetis also stressed

18. For instance, Uttal quotes Vimal (2009) who offers "a list of 40 different meanings of consciousness and argued that even this list was not exhaustive" [Uttal 2011, 271].

19. In an article from 2009, Bechtel mentions the same methods in favour of localization!

that the fMRI cannot grasp the activity of "silent neurons", activity that is important for many cognitive processes. Under such conditions, we wonder once more whether we can localize some mental functions in the brain. Logothetis' conclusion is that the multimodal approach for studying the brain's function is more necessary than ever.

Another already classical example of questioning the functioning of fMRI is the work of Vul *et al.* [Vul, Harris, Winkielman *et al.* 2009]. Vul *et al.* investigate the correlations between the behavioral and self-report measures of the personality or emotion and the measures of brain activation obtained using fMRI and show that

> these correlations are higher than should be expected given the (evidently limited) reliability of both fMRI and personality measures. [Vul, Harris, Winkielman *et al.* 2009, 274]

Vul *et al.* inquire about the questions and methods used in 54 articles! The authors of these papers try to find certain empirical data in order to

> bridge the divide between mind and brain: extremely high correlations between measures of individual differences relating to personality, emotion and social cognition, and measures of brain activity obtained using fMRI. [Vul, Harris, Winkielman *et al.* 2009, 274]

Without analyzing this investigation in detail, we introduce the conclusion of this article: Vul *et al.* claim that such correlations are "impossible high". Even if Vul *et al.* urge the authors of the articles under their investigations to correct the results of such correlations, we believe that these correlations would never be perfect![20] In our days, the most important and used method of investigating the brain for explaining the mind is neuroimaging (mainly non-invasive fMRI, but also PET, MEG, etc.). The neuroimaging tools help the researchers in cognitive neuroscience associate particular neuronal areas with cognitive functions. One of the problems with such associations is that we cannot be sure that the cognitive process we associate with some neuronal areas is totally isolated from other cognitive processes [D'Esposito 2010, 207].

> As a result, observed neural activity may be the result of some confounding neural computation that is not itself necessary for the execution of the cognitive process seemingly under study. [D'Esposito 2010, 208]

As D'Esposito emphasizes, no method in cognitive neuroscience is perfect!

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20. Uttal mentions quite many people that draw attention to the limits (theoretical and empirical) of fMRI [Uttal 2011]. In a very recent article, against "blobology" (Poldrack's expression for localization of function in some particular blobs), Poldrack pleads for an absolute methodological rigor in using fMRI [Poldrack 2011].

Another important problem in cognitive neuroscience is Raichle's "default network" [Raichle 2011] or the "dark energy of the brain"[21] [Raichle 2006], [Raichle & Mintun 2006]. The problem is that the brain "apparently uses most of its energy for functions unaccounted for—dark energy, in astronomical terms" [Raichle 2006, 1249]. In the last years, using PET and fMRI, researchers realized that the energy necessary for the brain to manage the demands of external environment is less than 1%. In other words, the brain's metabolism and its circulation for specific mental tasks in interaction with the environment require only a small part of the energy consumed by the brain. More exactly, it is about "the cost of intrinsic functional activity which far exceeds that of evoked activity and dominates the overall cost of brain function" [Raichle & Snyder 2009, 85]. But what does "intrinsic activity" mean? Raichle analyzes some possible answers to this question: spontaneous cognition, intrinsic functional activity facilitates responses to stimuli, interpreting, responding to and predicting environmental demands. Such a default function is a property of all brain areas. "Task-specific decreases from a resting state occur in many areas of the brain" [Raichle & Snyder 2009, 85]. Essentially, "the spatially coherent spontaneous activity of the fMRI BOLD signal persists despite major changes in levels of consciousness" [Raichle & Snyder 2009]. The problem is that fMRI and PET do not furnish information about this intrinsic energy of the brain. So, what kind of explanation do we get with fMRI tools?

Obviously, we do not have space in one article to analyze all major problems in cognitive neuroscience, but we just mention other problems. An essential problem is the relationship between sensorial inputs and perceptual states like the "constructive perception" or "perceptual filling in": the brain "*fills in perception* of the blind spot" [Baars & Gage 2010, 186]. The brain fills in color, patterns and motion! We perceive in full color and high resolution only at the center of gaze [Baars & Gage 2010, 158]. Regarding the color perceptual images, the fovea "subtends about four degrees of visual arc" [Baars & Gage 2010, 48].[22] However, we still do not understand how the "position-invariant recognition arises from ventral stream cells that have position preferences" [Banich & Compton 2011, 192]. The authors debate on the object recognition in relationship with the viewpoint-invariant or the viewpoint-dependent: what is the relationship between the neuronal patterns and the viewpoint from which the object is perceived and how does the brain create a 3D representation of an object (recognizable from any viewpoint) from 2D information received from the retina? How do we draw the line between what "we" really perceive and what is filled in by the brain? How could we combine the part that the eyes and the brain really "perceive" and what is filled in by the "brain"? Interestingly,

21. Raichle's "default network" or "dark energy of the brain" is not something sceptic in cognitive neuroscience, but something we cannot explain. He adds that "just as we will not understand evoked activity without first understanding intrinsic activity, so we will not understand consciousness without first understanding non-conscious activity, for in both instances the latter dominates the former" [Raichle 2011, 155].

22. About the same problem, see [Raichle 2011, 149].

it is the evolution of Brodmann areas during the last decades: today, there are around 100 Brodmann areas recognized in cognitive neuroscience. These areas are correlated with different specialized functions of the cortex (visual, auditory, motor, language, cognition). Nevertheless, in order to correlate such mental functions with neural areas, we have to take into account the white matter and subcortical regions.

> While the cortex is vital for cognitive functions, it interacts constantly with major 'satellite' organs, notably the thalamus, basal ganglia, cerebellum, hippocampus, and limbic regions, among others. [Baars & Gage 2010, 127]

It seems that localization becomes almost an impossible task in cognitive neuroscience.

Finally, we would like to point out some statements from a very recent handbook on cognitive neuroscience [Banich & Compton 2011] that is emblematic for the actual state of affair in this domain. The main idea is that regarding many topics, the authors underline many times that the results are still controversial.[23] For instance, Banich and Compton analyze the role of V4 for coding color. They consider that the area V4 is the most activated one for coding color, but there are other neuronal areas involved in this task as well. Therefore, regarding V4 as the area coding color (and nothing else) is "far too simplistic" [Banich & Compton 2011, 163].[24] Moreover, a difficult problem to solve is the integration of signals received by different modalities (for instance visual and auditory inputs) and "there is still much to be learned about how the sensory modalities interact" [Banich & Compton 2011, 173]. More and more researchers in cognitive neuroscience consider that "multi-modality integration" is necessary: the combination of the results offered by two apparatus, for instance, fMRI and EEG or fMRI and PET. With such combinations, we get a more "complete characterization of the different aspects of the brain activity during cognitive processing" [Laureys, Boly & Tononi 2009]. The conclusion is that all the problems investigated in this paper are caused by a notion, "correlations", that reflects a mixture of entities/processes of different

23. We give some examples from Banich and Compton's book: the area V4 "has been posited to play a special role in color perception, although that claim has been controversial" [Banich & Compton 2011, 161]. There are many such expressions throughout the whole book. For instance, in the first chapters: [Banich & Compton 2011, 153, 159, 161, 163, 182, 214, etc.].

24. "[...] (cells in V4 of the monkey are also responsive to properties other than color, such as line orientation, depth, and spatial frequency)" and "cells in areas V2 and V3 are sensitive to color" and finally "but the exact nature of the association—how to define different subregions, and what unique contribution each one makes to color perception—is still subject to debate among vision scientists" [Banich & Compton 2011, 163].

particular sciences, neuroscience and psychology. In this context, what could a philosopher recommend to the researchers in cognitive neuroscience?[25]

6 Cognitive neuroscience: science or a kind of "new engineering"?

In each "special science" (for instance, physics, neuroscience, psychology), we can find different theories/approaches (quantum mechanics, Einstein's theory of relativity, Fodor's LOT, some neuronal perspectives) that deal with particular entities (micro- and macro-particles, neurons and mental representations) and laws.[26] Such particular entities have questionable (relative or not) ontological status. Cognitive neuroscience deals with "correlations" that reflect the relationship between entities (mental and neuronal states) with questionable ontological status. Leaving aside the necessity of any argument whatsoever, it is quite clear that "correlation" has no ontological background, not even "questionable"/relative ontological background. Thus, cognitive neuroscience has no ontological entities and no laws. Therefore, from a standard framework (in which we define all other particular sciences like physics, neuroscience, cognitive psychology), cognitive neuroscience is not a real science but a pseudo-

25. Bassett and Gazzaniga relate the "complex system theory" with the notion of "levels" and "emergence" as a new framework for explaining the brain [Bassett & Gazzaniga 2005]. Introducing quite debatable notions like "emergence" and "levels", the authors conclude that (cognitive) neuroscience "desperately needs a stronger theoretical framework to solve the problems that it has taken on for itself" [Bassett & Gazzaniga 2005, 208]. (Gazzaniga also stated this kind of investigation in his very interesting paper from 2010.) If Gazzaniga (one of the father of cognitive neuroscience) asserts that neuroscientists need "desperately" a new theoretical framework and Bechtel (one of the best philosopher in cognitive (neuro)science) changes quite dramatically his optimism position, then it seems that something is wrong with the framework of cognitive neuroscience!

26. In a famous article from 1972, Anderson (Nobel Prize for physics) shows that reductionism is not appropriate to explain some physical phenomena [Anderson 1972]. That is, the explanations/theories of some macro-physical phenomena cannot be reduced to the quantum mechanics. In philosophy of mind, we can notice Fodor's article (two years after Anderson's paper). If, for Anderson, we can talk about a kind of organizational non-reductionism, Fodor establishes somehow a linguistic non-reductionism. Each special science (for instance, neuroscience or psychology) has its own taxonomy that cannot be reduced to basic science (physics) and we cannot mix the taxonomy of neuroscience with that of psychology [Fodor 1974]. Special sciences exist not because "of the nature of our relation to the world, but because of the way the world is put together: not all the kinds (not all the classes of things and events about which there are important, counterfactuals supporting generalizations to make) are, or correspond to, physical kinds." [Fodor 1974, 439]. Much more recently, Piccinini believes that "when it comes to explaining cognitive capacities, computational explanation is proprietary to psychology—it does not belong in neuroscience" [Piccinini 2006, 343].

science created by a mixture of information that describe entities/processes that belong to different "special sciences". In this context, it is clear that the enormous amount of correlations of the last decade created almost congestion for the young researchers. Maybe we can regard cognitive neuroscience as a new kind of "new engineering". However, we can make an analogy between brain imaging (the main tool of cognitive neuroscience in our days) and "neural networks" (a method in vogue between 1990 and 2005). Even if, since the end of the 1980s, connectionism has been quite important in cognitive science, the interest on neuronal networks among researchers strongly declined in the last years. We think that the brain imaging is in a similar situation: a lot of enthusiasm today, a decline tomorrow. Therefore, we predict that brain imaging or mind reading will have the same trajectory as connectionism: the mind reading (in particular) and cognitive neuroscience (in general) will become just a kind of new engineering. The main reason for this prediction is that the brain imaging does not really explain cognition nor the true relationship between mind and brain.[27] Like connectionism, cognitive neuroscience is not science, but only a kind of "new engineering".[28]

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27. Obviously, we could not show in this paper that people working in cognitive neuroscience need to change their paradigm of thinking/working. For a new paradigm of thinking, see [Vacariu 2005, 2008, 2011] and [Vacariu & Vacariu 2010]. In these works, we argue that the notion of the "world" or "universe" (in which we place brains, minds, microparticles and macroparticles, waves and corpuscules) needs to be replaced by epistemologically different worlds. Thus, mind and brain (body) (micro- and macro or waves and corpuscules) belong to epistemologically different worlds. In this new framework, the mind–body problem (and all problems from cognitive neuroscience presented in this paper) becomes a pseudo-problem. In the next book of Gabriel Vacariu, *Cognitive Neuroscience and the Hyperverse,* the problems from this paper and other problems of cognitive neuroscience will be analyzed in detail.

28. In 1999, Peter McLeod (with Rolls and Plunkett, wrote a book on connectionism in 1997) told us (particular conversation) that connectionism is already a kind of "engineering" not science [McLeod, Plunkett & Rolls 1998].

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